United States Department of Agriculture

Forest Service

Pacific Northwest Region

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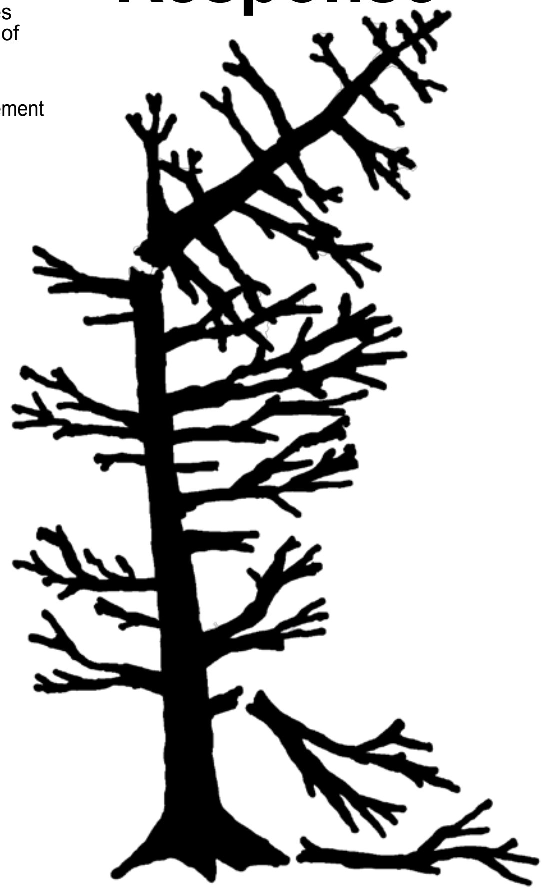
Bureau of Land Management

Field Guide for Danger Tree Identification and Response



Oregon OSHA

Associated Oregon Loggers, Inc.

Inside Front Cover

Field Guide for Danger Tree Identification and Response

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Introduction

Tree stability is determined by its location and the presence of defects, insects, disease, work activities, and weather conditions. If a tree is unstable, it may fail either partially or totally. If a tree fails, it is a danger to anyone who may be struck by it.

Guidebook objectives:

- To provide information to employers and managers that will help keep workers and others safe from exposure to tree dangers.
- To provide information to qualified people that will enable them to do the following:
  - ♦ Recognize tree conditions and determine tree failure potential.
  - ♦ Determine a tree's potential failure zone.
  - ♦ Understand how a work activity could induce a tree to fail, given failure potentials based on its condition
  - ♦ Determine if a tree presents a danger to people as a result of
    - ◊ Condition and failure potential
    - ◊ Work activity
    - ◊ Exposure
    - ◊ Whether or not the work activity is within the tree's potential failure zone

In this guide, general tree identification is discussed. Common diseases and defects that cause trees to fail are presented, along with how to identify them. Potential failure zones are described. Possible activities around trees are grouped into three classifications according to how they may induce tree failure. There is a discussion on how to determine if the tree is a danger to people, including examples. Finally, there is a discussion of what to do if there is a danger.

In this guide, a ***danger tree*** or a ***hazard tree*** is any tree or its parts that will fail because of a defect, and cause injury or death to people.

These guidelines are intended for use with any forest activity, at any location, including roads through forested areas, and are based on native tree species in Oregon and Washington. They are not intended to be used in developed recreation sites, although many of the procedures were adapted from guidelines for developed recreation sites (1).

Regulatory Basis

Oregon and Washington, as well as the Federal Occupational Safety & Health Administration (OSHA), have administrative rules about danger trees. The *Oregon rules are called Oregon Occupational Safety and Health Code Division 7 Forest Activities* and apply to all types of forest activities (2). For Washington, the rules are titled *Safety Standards for Logging Operations Chapter 296- 54 WAC* (3). The rules in both states apply to non-federal employers with employees operating on private or public land.

Federal OSHA regulations regarding requirements for protecting employees in the course of their work apply to federal agencies. The OSHA "General Duty" standard (29 CFR 960.8) requires agencies to, *"…furnish to each employee employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm"* (4). Trees with characteristics that indicate instability are considered recognized hazards. Federal agencies are required to identify trees that pose a danger to employees and establish means of protecting employees from that danger.

Federal OSHA rules regarding logging operations (29 CFR 1910.266) address specific means of protecting employees who are working in logging activities (5). They apply to federal employees.

The health and safety of Forest Service employees is addressed by the Health and Safety Code Handbook (6). Section 21.14 focuses on the identification of dangers to employees. It discusses the correction of dangers and what to do if they cannot be corrected.

The Bureau of Land Management addresses the health and safety of employees in BLM Manual 2-1, Safety and Health Management; and Handbook 2-2, Safety and Health for Field Operations (7, 8).

Chapter 2 of the BLM Manual 2-1, Safety and Health Management, describes the risk and management process that provides management with a systematic method for identifying and managing the risks associated with any BLM operation. Chapter 5 further discusses workplace and hazard assessments (7).

BLM handbook 2-2, Safety and Health for Field Operations, reviews the risk management process (29.1), and also provides additional information regarding the hazards of field activities (3.1). It also outlines prevention and mitigation methods (10.2). Section 23.3 specifically discusses the potential hazards of forestry activities. Safety and health requirements for contractor employees (field work) are discussed in section 20 (8).

The Region 6 Danger Tree Roadside Policy in the Forest Service Manual FSM 7700 – Transportation System, Chapter 30 – Operations and Maintenance, contains regulations about danger-tree identification and mitigation specific to USDA Forest Service roads in Oregon and Washington.

These rules contain language about danger trees. They are the overriding authority on the topic and should be referred to for a full understanding of the rules and standards.This document, titled *Field Guide for Danger Tree Identification and Response 2008,* is designed to implement the applicable rules. It does not replace the rules or standards.

Responsibilities

Employer Responsibilities

The employer has the responsibility to identify and mitigate dangers to workers from danger trees.

The Oregon Division 7 Forest Activities Standards requires an evaluation by employers of any tree or snag (dead tree) within reach of a work area to determine if it poses a danger to personnel. If a tree or snag poses a danger, it must be felled, or the work arranged to minimize danger to workers (2).

The Washington rule 296-54-507 (7), defines management's responsibility. Danger trees within reach of landings, roads, rigging, buildings or work areas shall be either felled before regular operations begin, or work arranged so that employees are not exposed to dangers involved (3).

Before work starts, and as often as necessary, a qualified person must evaluate danger trees within reach of a work area to determine if they pose a danger to personnel. If they pose a danger they must be felled, or the work must be arranged to minimize danger to workers.

Qualified Person

When an employer or manager is faced with danger trees, there should be people available with sufficient knowledge, training and experience, to follow a process for dealing with them.

A qualified person is defined as a person who has knowledge, training, and experience in identifying danger trees, their potential failure zones, and measures to eliminate the danger.

Conifer Identification

When assessing danger trees, it is important to be able to identify tree species. Diseases and defects that result in tree failure are more serious in certain tree species. The following is a brief description of the major native conifer species groups in Oregon and Washington forests.

Douglas-fir

Needles are about 1 in. long with a blunt tip and spirally arranged around the twig, but may be two-ranked in the shade. They are green above with two white bands beneath. Cones are 3-4 in. long with pitch and have forked bracts that are longer than the scales. The cones hang down from the twig. The bark has resin blisters when young, but is deeply furrowed and reddish-brown when old. Older inner bark is a mottled brown and yellow color similar to bacon.

True firs

Needles are 1-2 in. long and either spirally arranged or flat on the twig. Cones are 2-9 in. long and are perched upright on the twig. Bark when young has resin blisters. Older bark is gray to brown, and when cut, the older inner bark is purple in color.

Hemlocks

Needles are less than 1 in. long and in groups that appear to be either star-like or tend to stick out of the sides of the twig. Terminal branch tips have a natural bend. Cones hang down, are 1-3 in. long, and are cylindrical or egg-shaped. Bark is gray to brown with either narrow or flattened ridges.

Spruces

Needles are 1 in. long and sharp to touch. Cones are 1-4 in. long, hang down, and have thin scales with jagged edges. Bark is thin, gray-brown, and scaly.

Larches

Needles are 1-2 in. long on woody pegs in clusters of 20-40. They fall off in the winter. Cones are 1-2 in. long with papery bracts that are longer than the scales. Bark is reddish-orange and flakes off in irregularly shaped pieces.

Pines

Needles are 1-10 in. long and are in bundles of 2, 3, or 5 needles. Cones are 1-20 in. long with thick scales. Bark is gray to reddish brown and either furrowed or scaly.

Cedars

Needles are scale-like and flat on the twig. Cones are ½ to 1 in. long and are either round or long and thin. Bark is stringy or flaky and gray to brown.

Table 1 Important tree diseases and their chief hosts.

	Douglas fir	True fir	Hemlock	Spruce	Pine	Larch	Cedar	Hard-woods
Resinous	X			X	X	X		
Root & Butt Rots								
Laminated	X	X	X			X		
Armillaria	X	X	X	X	X			X
Annosus		X	X	X	X			X
Schweinitzii	X	X			X	X		
Tomentosus				X				
Black stain	X				X			
Ganoderma	X	X	X	X	X		X	X
Heart Rots								
Rust-red stringy		X	X					
Red ring	X	X	X	X	X	X		
Brown trunk	X		X		X	X		
Cedar pecky							X	
Sap rot	X	X	X	X	X	X		X
Dwarf mistletoe	X	X	X		X	X		
Fungal cankers	X	X			X			X

PROCESS FOR TREE EVALUATION AND ACTION

These are the steps the qualified person should take when dealing with potential danger trees:

1. Identify tree defects and determine the tree's potential to fail.
2. Determine the type of work activity.
3. Determine the potential failure zones.
4. Determine if the tree poses a danger to people and document the assessment.
5. Determine what action to take if the tree is a danger to people.

Step 1 – Identify tree defects and determine the tree's potential to fail

There are three levels of failure potential: low, likely, and imminent.

Low failure potential

Defective or rotten trees, snags, or their parts, have a low failure potential if they require considerable effort to make then fail during project implementation. They have a low probability of failure within 10 years of rating.

Likely failure potential

Defective or rotten trees, snags, or their parts, have a likely failure potential if they require some effort to make then fail during project implementation. They will have a high probability of failure within 3-5 years of rating.

Imminent failure potential

Defective or rotten trees, snags, or their parts, have an imminent failure potential if they require little effort to make then fail during project implementation. They will have a high probability of failure within one year of rating.

Failure potential is a function of tree condition. Trees with likely or imminent failure potentials may be classed as danger trees depending on the work activity, and whether the work activity is within the tree's potential failure zone. In order to define the potential failure zones, it is necessary to determine which tree part is likely to fail: entire tree, tree top, branches, or bark.

Trees with the following conditions may have either a low, likely, or imminent potential to fail. For example, some dead tops, dead trees, and fire-damaged or killed trees may be less stable than others. Trees with these conditions require an evaluation to determine which class to place them in. The following are general guidelines for danger-tree indicators. Refer to Appendix B for danger tree indicators that are specific for each geographic area in Oregon and Washington.

Table 2 General guidelines for danger tree indicators.

Failure Indicator	Failure Potential (FP)		
	Imminent	Likely	Low
Old dead trees >5 years	All species except cedar or larch	Cedar or larch	None
Recent dead trees < 5 yrs	None if no other indicators are present	All species except cedar or larch	Cedar or larch
Recent dead trees in root disease pockets	Trees in laminated root rot or annosus root disease pockets	Trees in other root disease pockets	Cedar
Live trees in root disease pockets	Trees with fading crowns and adjacent to live windthrown trees with root decay	Healthy appearing trees with adjacent windthrown live-infected trees of the same species; trees with fading crowns with no windthrown trees present	Trees with fading crowns and black stain root disease
Butt rot	Trees with ≥1 basal conks and extensive decay	Trees with ≥1 basal conks and moderate decay	None
Bole wounds, mistletoe cankers, or fungal cankers	True fir, hemlock, spruce, or hardwoods with < 50% cross-section of bole with sound wood; pine, cedar, larch, or Doug-fir with <25% cross-section of bole with sound wood	True fir, hemlock, spruce or hardwoods with 50-75% cross-section of bole with sound wood; pine, cedar, larch, or Doug-fir with 25 to 50% cross-section of bole with sound wood	True fir, hemlock, spruce or hardwoods with >75% cross-section of bole with sound wood; pine, cedar, larch, or Doug-fir with >50% cross-section of bole with sound wood
Leaning and/or root-sprung trees	Trees with recent (<5yr) lean (>15°) or old uncorrected lean with cracked or mounded soil or root damage	Trees with recent lean or old uncorrected lean without cracked or mounded soil or root damage	Trees with old corrected lean

Failure Indicator	Failure Potential (FP)		
	Imminent	**Likely**	**Low**
Undermined or severed root systems	Trees with <50% of structural roots remaining in the ground	Trees with 50-75% of structural roots remaining in the ground	Trees with >75% of structural roots remaining in the ground
Fire-damaged trees	Boles with <50% cross-section with sound wood or more than 1 quadrant (1/4 of the circumference) of damaged structural roots.	Boles with 50-75% cross-section with sound wood or one quadrant of damaged structural roots except cedar, larch, ponderosa pine, or sugar pine which are low FP	Cedar, larch, ponderosa pine, or sugar pine with >50% cross-section of bole with sound wood; other species with >75% cross-section of bole with sound wood
Dead tops or dead large branches (>5 in. dia.)	True fir, hemlock or hardwoods with significant decay (bark absent or conks), top or branch is imminent FP, not the whole tree	True fir, hemlock or hardwoods with little or no decay; Doug-fir, spruce, or pine tops not rust-killed, with significant decay.	Cedar, larch, or rust-killed tops on pine
Dwarf-mistletoe brooms	None	Trees with dead brooms ≥10 ft in diameter (broom is likely FP, not the whole tree)	Trees with live brooms; dead brooms <10 ft in diameter
Bole conks	See area tables in Appendix B, tables 5 - 8	Trees with ≥1 conks except larch or cedar	Larch or cedar with ≥1 conks
Black cottonwood branches	None	Live, large branches on mature trees if previous breakage is apparent	Live, large branches without previous breakage in the tree
Forked or multiple tops	None	Tops with embedded bark, cracks, conks, or decay (top is likely FP, not the whole tree)	Tops without embedded bark, cracks, conks, or decay; U-shaped tops
Frost cracks	None	Trees with weeping, gaping cracks or are associated with ≥1 conks	Trees with tight cracks and no conks
Bole damage or cracks	Trees with bole cracks showing movement and decay	Trees with bole cracks without movement or decay	Trees with tight cracks, not open
Detached tops, limbs, or loose bark	All species (parts are imminent FP, not the whole tree)	None	None
Broken or uprooted trees supported by other trees	Trees or parts that are not held securely	Trees or parts that are held securely	None
Height-diameter ratio (H:D)	Trees with >100 H:D	Trees with 80-100 H:D	Trees with <80 H:D
Balsam woolly adelgid	None	Infested subalpine fir with ≤10% live crown	Infested subalpine fir with >10% live crown
Multiple indicators	Two or more likely FP indicators that combine to increase FP to imminent (i.e. live spruce with recent lean without soil damage but bole conks are present)	Two or more low FP indicators that combine to increase FP to likely (i.e. live but fire-damaged fir with 85% cross-section of bole with sound wood but with an old corrected lean)	Two or more low FP indicators that do not combine to increase FP to likely (i.e. pine with 85% of structural roots remaining and live mistletoe branches)

Wind or snow loading

Wind or snow loading may increase the chances that a tree with decay or defect will fail. It is prudent to assume that as wind or snow loading increases, the potential for a tree to fail also increases.

Step 2 – Determine the type of work activity

No worker exposure in the potential failure zone of danger tree is allowed by state safety laws.

There are three categories of work activities.

- Traffic on roads.
- Activities that do not impact the tree such as walking or conducting non-motorized activities that do not involve tree contact.
- Motorized activities near the tree or activities that may cause the tree to be contacted.

Road traffic may or may not influence tree failure. This category is included because trees may fail and fall on vehicles or people congregated along roads, or they may fail and fall on roads and be driven into at a later time.

Walking by a tree or other non-motorized, non-tree contact activities are not likely to induce the tree to fail. The tree may fail due to either its condition or weather influences. Activities involving non-motorized, non-tree contact include planting and surveys.

Motorized activities or non-motorized activities that may contact the tree include road maintenance activities such as running a grader, culvert work, road construction, logging including timber falling, site preparation, road reconstruction, trail construction, and helicopter operations. All of these activities may induce tree failure.

Activity - Traffic on roads

Oregon OSHA Division 7, 437-007-0500 Roads (6). On those portions of roads under the direct control of the employer: (a) all danger trees that can fall or slide onto the roadways must be felled (2)

Washington 296-54-527 Truck roads (3) safe roadways. The following applies to roads under the control of the employer. All danger trees shall be felled a safe distance back from the roadway (3)

There are many miles of roads that may have danger trees adjacent to them. It is not possible to correct the danger-tree problem immediately, so it is necessary to prioritize the danger tree treatment workload. The treatment priority should be highest where people are most likely to be impacted by danger trees. Consideration of exposure level and traffic frequency provides a way to prioritize the workload.

There are three types of exposure: intermittent, short duration, and long duration. Intermittent exposure includes traffic driving by a defective tree. Short duration exposure includes people either stopping next to a defective tree, or stopping at an intersection that is next to a defective tree for up to 15 minutes. Long duration exposure includes people exposed to defective trees while parked at a trailhead, repairing a road, or working on a log landing.

Another aspect of exposure along roads is traffic frequency. Roads that have a higher traffic frequency expose more people to a danger tree than roads with a lower traffic frequency.

The longer people are exposed to a tree, the more opportunity there is for the failed tree to impact them. If exposure duration and traffic frequency are reduced, the opportunity for the tree to impact people is also reduced. The qualified person should consider traffic frequency and exposure duration when determining whether a tree posses a danger to people.

For specific direction, refer to policy about danger trees along roads. When developing the road treatment priority, consider trees in the following situations.

Table 3 Road treatment priority

Road	Exposure Duration	Failure Potential	Road Segment Priority	Priority Within Road
Areas where people stop and congregate such as interior roads of developed recreation sites, parking areas, active projects/contracts along the road where work is stationary such as culvert replacement and bridge construction.	Long			Highest
Intersections along operational maintenance level 3-5 roads, scenic vistas, geologic points of interest, where people are encouraged to stop. Refer to Appendix A for a description of maintenance levels.	Short	Imminent	High	
Areas along roads with higher traffic volumes such as operational maintenance level 3-5 roads not within intersections. Limited sight distance areas should be evaluated closely, as trees that have failed and are in the traveled way in these areas may be a surprise to drivers.	Intermittent but high frequency			Lowest
Haul routes				
Areas where people stop and congregate such as interior roads of developed recreation sites, parking areas, active projects/contracts along the road where work is stationary such as culvert replacement and bridge construction.	Long			Highest
Intersections along operational maintenance level 3-5 roads, scenic vistas, geologic points of interest, where people are encouraged to stop.	Short	Likely	Medium	
Areas along roads with higher traffic volumes such as operational maintenance level 3-5 roads not within intersections. Limited sight distance areas should be evaluated closely, as trees that have failed and are in the traveled way in these areas may be a surprise to drivers.	Intermittent but high frequency			Lowest
Haul routes				
Areas with low traffic volumes such as operational maintenance level 2 roads.	All	Imminent or likely	Low	

Activity – Non-motorized, non-tree contact

These are activities that involve walking near trees without touching them. They are also non-motorized. The premise behind this activity type is that trees are less likely to fail if they are not contacted, and workers are more likely to recognize tree dangers if they are not focused on operating vehicles or machinery. Examples include tree planting, inventory (any type), surveying, walking to a jobsite along a trail, and designating timber.

With this type of activity, it is important to recognize trees that have an imminent failure potential. These trees may fail at any time so they are a danger to people regardless of the activity type. Because these trees expose people to dangers, only qualified employees under the direct supervision of the employer should enter the tree's potential failure zone.

There will also be trees that have a likely potential to fail. In order to determine if the tree is a danger to people, the qualified person needs to evaluate the tree condition, activity, and whether or not the person will be within the potential failure zone. If the qualified person determines that the likely failure potential tree does not represent a danger, people should work through the potential failure zone quickly so as to minimize exposure time and avoid tree contact. If the tree does represent a danger, it should be removed or the work activity should be excluded from within the potential failure zone.

Activity – Motorized or tree contact

Motorized activities, or those activities that may contact the tree, include road construction, logging, timber falling, tree climbing, site preparation, trail construction, and helicopter operations. The premise behind this activity type is that vibration due to machine operation, air movement in the case of a helicopter, or tree contact by a person, machine, log, or operating line may induce tree failure. As a result of noise or worker focus on the job task, the person might not recognize the danger or notice the failure beginning to take place, and miss the opportunity to escape.

Step 3 - Determine the potential failure zone

The potential failure zone is the area that could be reached by any part of a failed tree.When a tree fails, the tree or its parts may strike other trees and cause them to fail as well. The parts may slide or roll. When a tree is being felled, it may strike other trees or debris on the ground and fling material a considerable distance. This is especially true in dead timber. The qualified person needs to be aware of these situations when determining the potential failure zones.

Total Tree Failure - Potential Failure Zone

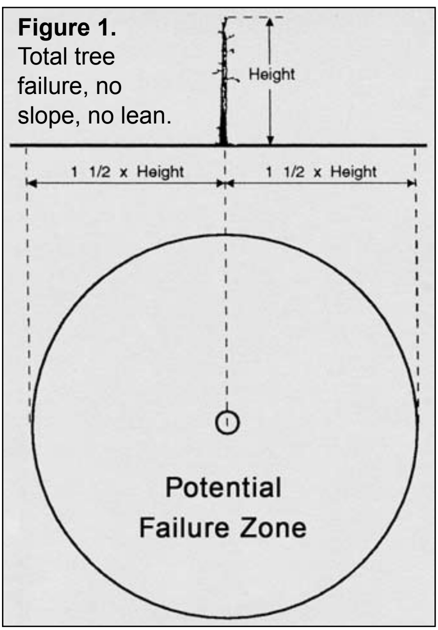


Figure 1. Total tree failure, no slope, no lean.

The failure zone is defined as the area on the ground that could be reached by any portion of the tree that may collapse. When determining the failure zone, the following conditions must be evaluated:

- Ground slope.
- Direction of lean.
- Height of the tree.

❖ Level or sloped ground; no discernible lean

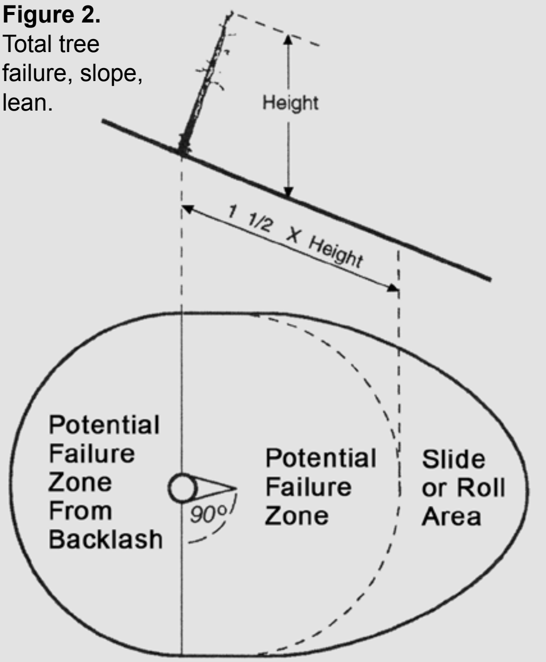
The failure zone is a circle around the tree with a radius of at least 1½ times the total tree height. On sloped ground, the failure zone downhill of the tree may have to be extended whatever distance is necessary to protect people.

❖ Level or sloped ground; lean in any direction

The failure zone is an area at least 1½ times the tree height beginning at the tree base then extending towards the direction of the lean and out 90 degrees on either side of the tree from the lean direction.

The area behind the lean is not within the failure zone. Be aware that if equipment, lines, moving logs, or falling timber contacts a likely or imminent failure potential tree, the contact could force a backlash opposite to the lean, and create an additional danger during the time of impact beyond the potential failure zone.

Figure 2. Total tree failure, slope, lean.

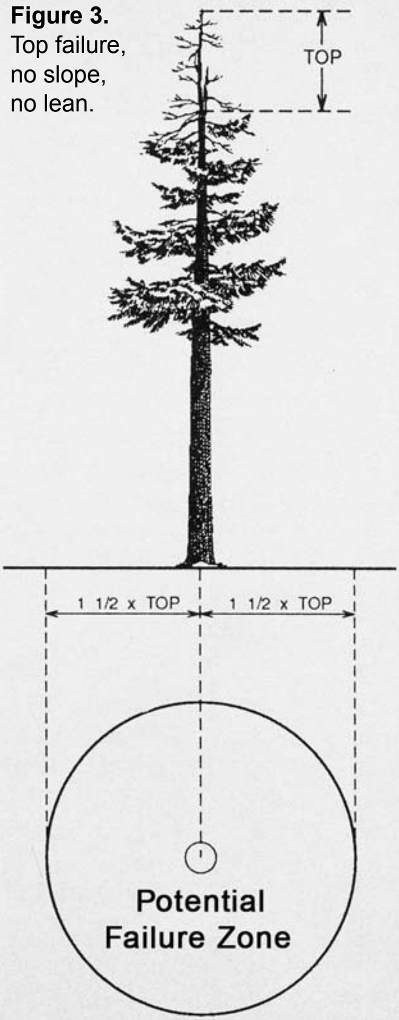


On sloped ground where the dislodged section may roll downhill, the potential failure zone must be extended on the downhill side for whatever distance is necessary to protect people.

Tree Part Failure – Potential Failure Zone

The area on-the-ground that could be reached by a dislodged top, branch, slab, or chunk is called the potential failure zone for a part failure. When determining the zone, evaluate the following conditions:

Figure 3. Top failure, no slope, no lean.



- Ground slope.
- Amount and direction of lean.
- Length of the part that could dislodge.

❖ Level or sloped ground; no discernable lean

Determine the length of the part that could dislodge. The failure zone forms a circle around the tree with a radius equal to at least 1½ times the length of the dislodged part. On sloped ground where the dislodged part may slide or roll down hill, the failure zone must be extended on the down-hill side for whatever distance is necessary to protect people.

❖ Level or sloped ground; lean in any direction

Determine the length of the part that could dislodge. Determine the amount of lean (horizontal distance from where the part could dislodge relative to the base). The failure zone is the distance determined by adding 1½ times the length of the dislodged part to the lean amount. This distance would be applied to an area beginning at the tree base then extending towards the direction of the lean and out 90 degrees on either side of the tree from the lean direction.

The area behind the lean is not within the failure zone. Be aware, however, that if equipment, lines, moving logs, or falling timber contacts a likely or imminent failure potential tree, the contact could force a backlash opposite to the lean and create an additional danger during the time of impact beyond the potential failure zone. On sloped ground where the dislodged part may slide or roll downhill, the potential failure zone is extended on the downhill side for whatever distance is necessary to protect people.

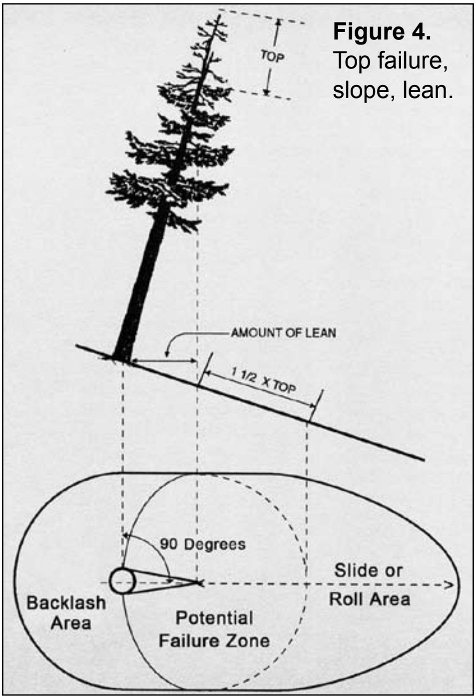


Figure 4. Top failure, slope, lean.

Step 4 – Determine if the tree poses a danger to people

Not all trees with a likely or imminent potential to fail will be danger trees. For instance, if the work activity is outside of the potential failure zone, the tree is not a danger tree. If the work activity is mechanized, the tree has a likely failure potential, and the work is within the failure potential zone, the tree could be considered a danger tree. The following should be considered when determining if a tree poses a danger to people:

- Evaluate the tree and determine its condition and failure potential.
- Determine if the activity is likely to cause the tree to fail.
- Identify the potential failure zone and if the work activity is within the failure zone.
- Make a judgment about whether or not the tree is a danger to people and document the assessment.
- If the tree is a danger, remove the danger by taking the tree down, or arrange the activity so that people are not in the potential failure zone.

The following three examples illustrate the process a qualified person should follow when evaluating trees:

Example 1

Part 1. Assume there is a skyline logging operation. You as the qualified person notice that behind the landing, the standing trees look abnormally faded. There is a history of dying trees in the area combined with some live trees with sparse crowns. There is some basal resin and bark staining on them. There has been some windthrow. When you chop at the root collar and pull the bark away, you discover white latex-like mycelial fans.

You conclude that the trees have Armillaria root disease and have a likely failure potential. Next, you determine that the landing is within the potential failure zone of the trees. The activity is motorized, and while it is not likely that anything will strike the trees, wind and vibration may induce them to fail. You recognize that the landing crew will be within the potential failure zone of the trees for a long time. Your conclusion is that the trees pose a danger to workers and need to be felled or the landing moved.

Part 2. Assume there is a tree planting operation in the unit logged near the landing previously discussed. You, as the qualified person, notice that around the unit boundary, many of the standing trees look abnormally faded. You don't notice any windthrow. There are mushrooms around the base of several of the trees. There is some basal resin and bark staining on them. When you chop at the root collar and pull the bark away you discover white latex-like mycelial fans.

You conclude that the trees have Armillaria root disease and have a likely potential to fail. Next, you determine that the planting job site is within the potential failure zone of the root diseased trees. The activity is tree planting, and it is not likely that anything will strike the trees and cause them to fail. Your conclusion is that the Armillaria root diseased trees do not pose a danger to workers, so the area around them can be planted. You require that the planting crew work rapidly through the area and avoid the area on a windy day.

Example 2

Assume that you are evaluating trees along a haul-route road. You notice two very similar white fir trees in two locations. These trees have one Indian paint fungus conk on the bole. You conclude the trees have some heart rot and have a likely potential for failure. One tree is on the far side of a curve at the bottom of a long steep grade. The other is along a straight stretch of road. Exposure will be intermittent. Next, you determine the potential failure zone and realize that the portion of the road traveled is within the potential failure zone. You think that when the trees fail they may not actually hit any traffic, but that traffic may run into them, especially the one on the curve.

You conclude that the trees pose a danger to people and need to be taken down.

Example 3

You are evaluating a tree-planting job. The unit being planted has many dead trees and a few large live trees left. You notice that the bark looks loose on most of the dead trees. One of the green trees has a recent lean, and you suspect it is root sprung since there is evidence of recent soil cracking at the base. You also notice that there are some dead trees that are hung up in some other trees. On the other side of the unit, there are a few live trees standing straight with heart-rot conks on the bole.

You conclude that the leaning root sprung trees, the trees that are hung up, and the trees with the loose bark have an imminent potential to fail. Because these trees have an imminent failure potential, and their potential failure zones include the area to be planted, you conclude that the trees are a danger to employees. The areas cannot be safely planted without removing the danger by taking the trees down.

The straight green trees with heart rot are different. While they have a likely potential for failure, the exposure under them will be short duration, and the activity is not likely to cause the trees to fail since there will be no vibration or tree contact. You decide to let a crew plant under them if they move through rapidly and do not linger under the trees.

Step 5 – Action if tree is a danger to people

As a qualified person, when you examine trees, it is important to record your work because you might be expected to justify your results.

People are not to be exposed to danger trees. If after considering the tree condition and activity, and recording your observations, it is determined that the tree poses a danger to people, the tree either needs to be taken down or the work arranged so that people are not exposed to the danger.

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3. Washington Safety Standards for Logging Operations 997. Chapter 296-54-WAC.
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7. BLM Manual 2-1, Safety and Health Management.
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9. Goheen, E.M., and E.A. Willhite 2006. Field guide to the common diseases and insect pests of Oregon and Washington conifers. USDA Forest Service, Pacific Northwest Region, R6-NR-FID-PR-01-06, Portland, OR. 325p.

Citation example: (9, Pg 15) means page 15 in Goheen and Willhite.

Appendix A Forest Service road maintenance levels

Table 4 Forest Service road maintenance levels.

	Maintenance Level				
Parameters	**1**	**2**	**3**	**4**	**5**
Traffic type	Open for non-motorized uses. Closed to vehicles licensed to be on the public road system.	Administrative, permitted dispersed recreation, specialized commercial haul. Maintained for high clearance vehicles.	All National Forest traffic, general use, commercial haul, maintained for passenger cars.		

Appendix B Defect and Disease Identification

It is important to be able to identify diseases and defects that affect tree stability. Detailed information about disease and defect identification in Oregon and Washington forests can be found in the Field guide to the common diseases and insect pests of Oregon and Washington conifers by Goheen and Willhite (9).

Tree condition and visible indicators often determine failure potential. There are several factors that should be included in that evaluation. Following are tables of significant indicators specific to different areas in Oregon and Washington.

Table 5 Indicators for SW & Central Oregon.

Failure Indicator	Imminent	Likely	Low
Old dead trees	All species but cedar and larch	Cedar and larch	None
Recent dead trees (<5 years)	None	All species except cedar and larch	Cedar and larch
Recent dead host trees in root-disease pockets	Laminated root rot or annosus root disease pockets	Other kinds of root disease pockets	Resistant or immune tree species in root disease pockets
Live host trees in root-disease pockets	Symptomatic with adjacent windthrown infected trees	Non-symptomatic trees with adjacent windthrown infected trees, and symptomatic trees without windthrown trees	Immune or resistant tree species in pockets; non-symptomatic hosts with no adjacent windthrow
Butt rot	Schweinitzii or Tomentosus conks and extensive decay	Schweinitzii or Tomentosus conks and moderate decay	Little or no butt rot
Bole wounds, mistletoe cankers, or fungal cankers	Hemlock, true fir, or hardwoods with <50% cross-section of bole with sound wood	Hemlock, true fir, or hardwoods with 50 to 75% cross-section of bole with sound wood; Douglas-fir, pines, larch, cedar, or spruce with <50%.	Hemlock, true fir or hardwoods with >75% bole cross-section with sound wood; Douglas-fir, pine, larch, or cedar with >50%
Leaning and/or root-sprung trees	Recent (<5yr) lean (>15°) or old uncorrected lean with disturbed soil or root damage	Recent lean or old uncorrected lean without disturbed soil or root damage.	Corrected old lean
Undermined or severed roots	<50% of the structural roots remaining in the ground.	50 to 75% of the structural roots remaining in the ground	>75% of structural roots remaining in ground
Fire-damaged trees	Any tree species with <50% cross-section with sound wood in bole or more than one quadrant of damaged structural roots	50 to 75% cross-section of bole with sound wood, or one quadrant of damaged structural roots except cedar, ponderosa pine, sugar pine, and larch	Cedar, ponderosa pine, sugar pine, and larch with >50% and other species with >75% of bole cross-section sound
Dead tops or large dead branches (≥5” diameter)	True fir, hemlock, or hardwoods with significant decay	True fir, hemlock or hardwoods with little decay; Douglas-fir, spruce, or pine with substantial decay	Cedar, larch or Douglas-fir, and pine tops killed slowly by rust that show little evidence of decay
Dead Douglas-fir mistletoe brooms	None	Douglas-fir with large, dead brooms ≥10ft diameter.	Douglas-fir with dead brooms <10ft diameter
Quinine conks	Trees with ≥ 1 conks	None	None

Failure Indicator	Imminent	Likely	Low
Other conks	≥1 conk and extensive decay based on tree species and type and extent of rot	True fir, hemlock, or hardwoods with ≥1 conk and little decay evident; Douglas-fir, pine, spruce, cedar, or larch with ≥5 conks; ≥1 conks ≥8 in. diameter	Douglas-fir, pine, spruce, cedar, or larch with <5 conks; true firs, hemlocks, or hardwoods with no conks
Black cottonwood branches	Live or dead branches with evidence of substantial decay	Live, large branches on mature trees with evidence of breakage	Live branches without decay or breakage
Forked or multiple tops	None	Tops with embedded bark, cracks, decay, or conks	U-shaped forks - no embedded bark, cracks, decay, or conks
Frost cracks	None	Gaping, weeping cracks or ≥1 conks associated with crack	Cracks tight with no sign of decay or weeping
Bole damage or cracks	Damage, or cracks with independent movement and/or substantial decay	Damage or cracks without movement or with moderate decay.	Damage or cracks with insignificant decay or no decay; callus has formed
Detached tops, limbs, or loose bark	All species	None	None
Broken or uprooted trees supported by other trees	Trees not held securely; failure potential determined by type of support.	Trees held securely; failure potential determined by amount and type of support.	Trees not broken or uprooted
Height:diameter ratio (H:D)	>100% H:D ratio	80-100% H:D ratio	<80% H:D ratio
Multiple Indicators	Two or more likely FP indicators if synergistic effects	Multiple FP indicators if no synergistic effects	Lacks multiple indicators

Table 6 Indicators for Eastern Washington.

Failure Indicator	Imminent FP	Likely FP
Old dead trees	All species with evidence of obvious decay except cedar, larch, or fire-killed subalpine fir or spruce	Cedar, larch, or fire-killed subalpine fir or spruce
Recent dead trees (<5 years)	None	All species except cedar or larch
Recent dead or live trees in root-disease pockets	Symptomatic trees in any root disease pocket with adjacent live windthrown trees with root disease	Symptomatic trees in any root disease pocket without live windthrown trees with root disease
Butt rot	None	Trees with Schweinitzii conks and decay with sound-rind thickness ≤15% of bole dia; >15% would be low FP; spruce with Tomentosus conks and decay
Bole wounds, mistletoe cankers, or fungal cankers	None	Hemlock, true fir, or hardwoods with 50-75% cross-section of bole with sound wood
Leaning and/or root-sprung trees	Trees with recent (<5yr) lean (>15^{o}) or old uncorrected lean with cracked or mounded soil and/or root damage	Trees with recent lean or old uncorrected lean without cracked or mounded soil or root damage.
Undermined or severed roots	Trees with <50% of the structural roots remaining in the ground.	Trees with 50 to 75% of the structural roots remaining in the ground
Fire-damaged trees	Boles with <50% cross-section with sound wood or more than one quadrant of damaged structural roots	Boles with 50 to 66% cross-section with sound wood, or one quadrant of damaged structural roots
Dead tops or large dead branches (≥5” dia)	None	True fir, hemlock, hardwoods, or ponderosa pine without rust disease (top or branch is likely FP, not the whole tree)
Dwarf mistletoe brooms	None	None (low FP)
Quinine conks	None	Trees with ≥1 conks
Red ring rot (white speck) conks	None	Douglas-fir, pine, spruce, cedar, or larch with ≥5 conks separated by ≥15 ft; ≥1 conks ≥4 in. diam.
Other conks	None	True fir, hemlock, or hardwoods with ≥1 conks
Black cottonwood branches	None	Live, large branches on mature trees if previous breakage is apparent
Forked or multiple tops	None	Tops with embedded bark, cracks, decay, or conks (top is likely FP, not the whole tree)
Frost cracks	None	Trees with gaping, weeping cracks or are associated with ≥1 conks

Failure Indicator	Imminent FP	Likely FP
Bole damage or cracks	Trees with substantial damage, including cracks with independent movement and decay	Trees with damage/cracks without movement or significant decay.
Detached tops, limbs, or loose bark	All species (parts are imminent FP, not the whole tree)	None
Broken or uprooted trees supported by other trees	Trees or parts that are not held securely; failure potential is determined by amount and type of support.	Trees or parts that are held securely; failure potential is determined by amount and type of support.
Height:diameter ratio	Trees with >100% H:D ratio	Trees with 80-100% H:D ratio
Balsam woolly adelgid	None	Infested subalpine fir with ≤10% live crown
Multiple Indicators	Two or more likely FP indicators that combine to increase FP to Imminent	Two or more low FP indicators that combine to increase FP to Likely

Table 7 Indicators for Western Oregon & Washington

Failure Indicator	Imminent FP	Likely FP
Old dead trees	All species except cedar or larch	Cedar or larch
Recent dead trees (<5 years)	None	All species except cedar or larch
Recent dead trees in root-disease pockets	Dead trees within 30 ft of live windthrown trees with decayed roots	All species
Live trees in root-disease pockets	Trees with fading crowns within 30ft. of live windthrown trees with decayed roots	Trees with fading crowns in any root rot pocket except black stain which has low FP until death; *non-symptomatic* trees within 30ft. of live windthrown trees of same species with decayed roots
Butt rot	Trees with basal conks and bole cracks	Trees with Schweinitzii or Tomentosus conks and evidence of decay (swollen butt)
Bole wounds, mistletoe cankers, or fungal cankers	Hemlock, true fir, or hardwoods with <50% cross-section of bole with sound wood; Douglas-fir, pines, larch, cedar, or spruce with <25% cross-section of bole with sound wood	Hemlock, true fir, or hardwoods with 50 to 75% cross-sectional area of sound stem wood; Douglas-fir, pines, larch, cedar, or spruce with 25 to 50% cross-section of bole with sound wood
Leaning and/or root-sprung trees	Trees with recent (<5yr) lean (>15^{o}) or old uncorrected lean with cracked or mounded soil and/or root damage	Trees with recent lean or old uncorrected leans without cracked or mounded soil or root damage.
Undermined or severed root systems	Trees with <50% of the structural roots remaining in the ground.	Trees with 50 to 75% of the structural roots remaining in the ground
Fire-damaged trees	Boles with <50% cross-section with sound wood or more than one quadrant of damaged structural roots	Boles with 50 to 75% cross-section with sound wood, or one quadrant of damaged structural roots except cedar, ponderosa pine, sugar pine, and larch which are Low FP
Dead tops or large dead branches (≥5 in. dia.)	Dead with conks and significant decay (top or branch is imminent FP, not the whole tree)	Recently dead true fir, hemlock or hardwoods; older Douglas-fir, spruce, or pine without rust disease
Dwarf mistletoe brooms	None	Douglas-fir with large, dead brooms (broom is likely FP, not the whole tree)
Quinine conks	None	Trees with one or more conks
Other conks	None	True fir, hemlock, or hardwoods with ≥1 conks; Douglas-fir, pine, spruce, cedar, or larch with ≥5 conks
Black cottonwood branches	None	Live, very large branches where previous breakage is apparent

Failure Indicator	Imminent FP	Likely FP
Forked or multiple tops	None	Multiple tops in true firs, hemlock, or hardwoods; any species with tight V-forks and embedded bark ≥3 ft long or cracks (top is likely FP, not the whole tree)
Frost cracks	None	Trees with gaping, weeping cracks or cracks are associated with ≥1 conks
Bole damage or cracks	Trees with bole cracks showing movement	Trees with damage/cracks without movement or significant decay.
Detached tops, limbs, or loose bark	All species (parts are imminent FP, not the whole tree)	None
Broken or uprooted trees supported by other trees	Trees or parts that are not held securely; failure potential is determined by amount and type of support	Trees or parts that are held securely; failure potential is determined by amount and type of support
Height:diameter ratio (H:D)	None	Trees with >100% H:D ratio
Balsam woolly adelgid	None	Infested subalpine fir with ≤10% live crown
Multiple Indicators	Two or more likely FP indicators that combine to increase FP to imminent	Two or more low FP indicators that combine to increase FP to likely

Table 8 Indicators for NE Oregon & SE Washington

Failure Indicator	Imminent FP	Likely FP
Dead Trees	PP<16"≥5y; ≥16"≥10y; WL≥20y; DF; LP≥5y; GF,SAF,ES, hardwoods≥3yr	PP<16"<5y; ≥16"<10y; WL 5-19y; LP, DF<5y; GF,SAF,ES, hardwoods<3yr
Recent dead trees in root disease pockets	DF, GF, or SAF in laminated root rot pockets; host trees in any root rot pocket with adjacent windthrown live trees with root disease	Host trees in any root disease pockets other than laminated root rot without adjacent windthrown live trees with root disease
Live trees in root disease pockets	DF, GF in laminated root rot pockets GF, SAF in annosus root rot pockets; both with crown/root collar symptoms/ and adjacent live windthown trees with root disease	Host trees in any root disease pocket without crown or root collar symptoms but with adjacent live windthrow trees with root disease
Butt rot	DF, WL with Schweinitzii conks and extensive decay; ES with Tomentosus with extensive butt rot associated with any indicators	DF, WL with Schweinitzii conks and moderate decay; ES with Tomentosus with moderate butt rot associated with any indicators
Bole wounds, mistletoe cankers, or fungal cankers	GF, SAF, spruce, hardwoods with <50% cross-section of bole with sound wood; DF, pines, or WL with <25% cross-section of bole with sound wood.	GF, SAF, spruce, hardwoods with 50 to 75% cross-sectional area of sound stem wood; DF, pines, or WL with 25-50% cross-section of bole with sound wood.
Leaning and/or root-sprung trees	Trees with recent (<5y) lean (>15°), or old uncorrected lean with cracked or mounded soil and/or root damage	Trees with recent lean or old uncorrected lean without cracked or mounded soil or root damage.
Undermined or severed root systems	Trees with <50% of the structural roots remaining in the ground	Trees with 50 to 75% of the structural roots remaining in the ground.
Fire-damaged trees	Boles with <50% cross-section with sound wood, or more than one quadrant of damaged structural roots.	Boles with 50 to 75% cross-section with sound wood, or one quadrant of damaged structural roots except PP and WL, which are Low FP
Dead tops or large dead branches (≥5 in. dia)	True firs or hardwoods with significant decay (top or branch is imminent FP, not the whole tree)	True firs or hardwoods with no decay or minor decay. Also DF, ES, or pines with tops not rust-killed
Dwarf mistletoe brooms	None	PP or DF with large, dead brooms ≥10ft dia. (broom is likely FP, not the whole tree)
Quinine conks	Trees with ≥1conks	None
Indian paint fungus conks	Trees with large single or smaller multiple conks and at least one additional indicator of associated defect with indications of extensive decay	Trees with large single or smaller multiple conks without additional indicators. Tight dry frost cracks are not indicators.
Red ring rot (white speck) conks	None	DF, pines, ES, or WL with 5 or more red ring rot (white speck) conks

Failure Indicator	Imminent FP	Likely FP
Saprot (pouch) conks	Dead trees with >15% decayed rind; pouch conks & Indian paint conks on recent dead GF	Trees with conks on one or more panels associated with beetle strip attacks
Hardwood conks	None	Hardwoods with any conks or evidence of ganoderma root rot
Black cottonwood branches	None	Live, large branches on mature trees if previous breakage is apparent
Forked or multiple tops	None	Tops with embedded bark, cracks, decay, or conks (top is likely FP, not the whole tree)
GF with frost cracks (no conks)	None	Fir with gaping, weeping cracks without Indian paint or other conks
Bole damage or cracks	Trees with substantial damage, including open cracks with independent. movement and decay	Trees with damage/cracks without movement or significant decay.
Detached tops, limbs, or loose bark	All species (parts are imminent FP, not the whole tree)	None
Broken or uprooted trees supported by other trees	Trees or parts that are not held securely; FP is determined by amount and type of support.	Trees or parts that are held securely; FP is determined by amount and type of support.
Height:diameter ratio (H:D)	Trees with >100% H:D ratio	Trees with 80 to 100% H:D ratio
Balsam woolly adelgid	None	Infested subalpine fir with ≤10% live crown
Multiple Indicators	Two or more likely FP indicators that combine to increase FP to Imminent	Two or more low FP indicators that combine to increase FP to Likely

PP=ponderosa pine, LP=lodgepole pine, DF=Douglas-fir, GF=grand fir; SAF=subalpine fir, WL=western larch; ES=Engelmann spruce, FP=Failure potential

The following is a discussion of each disease, defect, and failure indicator:

Root and butt rots

Root and butt rots also called root diseases may cause a tree to fail if disturbed. Sites with root and butt rots will have danger-tree problems for decades unless treated, because these diseases remain on the site for long periods and spread slowly among root systems. There are several important root and butt rots: laminated root rot, Armillaria root disease, annosus root disease, black stain root disease, tomentosus root rot, Schweinitzii root and butt rot, and Ganoderma butt rot.

- ***General symptoms and indicators***
  - Decline of the entire live crown is characterized by fading foliage, dying branches, premature shedding of older needles, and terminal and lateral shoot-growth reduction (Figure 5).
  - Distress cone crops sometimes are present.
  - Butt rot occurs often without crown symptoms.
  - Basal resin flow and bark staining may be present (Figure 6).
  - Mushrooms or conks often occur on the roots or at the root collar of infected trees (Figure 7).
  - Windthrow or wind shatter of surrounding trees may be present (Figure 8).
  - Groups or pockets of trees are affected usually with dead and dying trees of various sizes and levels of decay on the site (Figure 9).
  - Bark beetles attack trees stressed by root disease (Figure 10).
  - The incidence of root and butt rots generally increases with the number of harvest entries.

- ***Laminated root rot*** *caused by Phellinus weirii*
  - Laminated root rot is the most dangerous root disease regarding tree failure.
  - The disease can readily affect even the healthiest trees in the stand and often causes green trees to fail due to extensively decayed root systems.
  - Primary hosts are Douglas-fir, white and grand fir, and mountain hemlock.
  - It is distinguished from the other root diseases by the presence of red setal hyphae in the decayed wood or in mycelium that look like tiny reddish whiskers when viewed with a hand lens.
  - Decayed wood is laminated with pitting on both sides of the laminations (Figure 11).

- ♦ Mycelium on the surface of infected roots called ectotrophic mycelium can be found on live and recently killed trees.
- ♦ Conks are difficult to find and occur infrequently on the undersides of infected roots or logs.
- ♦ Live infected trees are frequently windthrown with exposed decayed roots (Figure 12).
- ♦ Root disease pockets can be small to several acres in size characterized by abundant windthrow with almost no roots (root balls).
- ♦ Trees adjacent to an infection center may not show symptoms of infection making them difficult to rate for failure potential.
- ♦ Symptoms may not occur until much of the root system is colonized and dead.
- ♦ Trees at the edges of pockets are often infected without symptoms.

- ***Armillaria root disease*** *caused by Armillaria ostoyae*
  - ♦ Armillaria root disease affects many tree species. However, it is found primarily on weakened and stressed true firs and Douglas-fir.
  - ♦ Root decay may be extensive; trees with this root disease should not be considered wind firm whether they are live or dead.
  - ♦ Unlike laminated root rot, Armillaria-killed trees most often die standing (Figure 9).
  - ♦ Trees adjacent to an infection center may not show symptoms of infection.
  - ♦ Infected trees may have copius resin flow or resin soaking of the butt (Figure 6).
  - ♦ White latex-like mycelial fans are found under the bark in infected roots and at the root collar (Figure 13).
  - ♦ Rhizomorphs or fungal “shoestrings” resemble small black roots but instead are packed with white mycelium.

- Honey-colored mushrooms may be found at the base of infected trees in the fall (Figure 7).
- Advanced decay is yellow, stringy, and water soaked.

- ***Annosus root disease*** *caused by Heterobasidion annosum*
  - Annosus root disease is especially dangerous in grand fir and white fir.
  - It is the one of the most difficult root diseases to identify.
  - Infected trees may exhibit symptoms of root disease or they may not have symptoms if the decay is confined to the butt and lower bole (common in hemlock and spruce).
  - Conks may be found above ground in old stumps or in root crotches of living trees, or below ground on portions of roots in the duff layer or upper reaches of the soil (Figure 14).
  - Conks may appear as small pustules on roots (Figure 15).
  - Butt decay predisposes trees to windthrow and breakage (Figure 16).
  - Incipient decay is a light-brown to reddish stain in the outer heartwood.
  - Advanced decay is white and stringy to laminated. Elongated pits occur only on one side of the laminations with no setal hyphae.

- ***Black stain root disease*** *caused by Leptographium wageneri*
  - Black stain root disease causes a vascular wilt and not decay.
  - Trees die standing and rarely fail until after they die.
  - Characteristic sign is a brown to purplish-black stain in older sapwood that fades in dead trees.

- ♦ Black stain kills all ages of pine on the eastside and young Douglas-fir on the westside.
- ♦ Black stain is often associated with soil disturbance along roads and with soil compaction.
- ♦ The disease is spread by root grafts and by root feeding insects that are attracted to stressed trees.

- ***Tomentosus root rot*** *caused by Inonotus tomentosus*
  - ♦ Tomentosus root rot is most commonly found in Engelmann spruce (Figure 17).
  - ♦ It typically does not cause extensive damage but is locally important in the Cascades and Blue Mountains.
  - ♦ This disease may be completely hidden in trees which still have extensive butt rot.
  - ♦ Trees with crown symptoms are not common, making the disease difficult to detect.
  - ♦ Mushrooms are small, cinnamon-colored, leathery, and may appear in the fall near the base of defective trees (Figure 18).
  - ♦ When infected trees are mature, they are more likely to be severely rotted in the roots and butt.
  - ♦ Advanced decay is a white pocket rot.

- ***Schweinitzii root and butt rot*** *caused by Phaeolus schweinitzii*
  - ♦ Schweinitzii root and butt rot affects many tree species. However, it is found primarily on large old Douglas fir.
  - ♦ The fungus is also called the velvet-top fungus or the cow-pie fungus because of its distinctive conks (Figure 19)
  - ♦ Fresh fruiting bodies are velvety to the touch and have a brightly colored yellow margin but die, turn brown, and last for about two years (Figure 20).

- Trees with butt rot may have fruiting bodies growing on or near the butt.
- On the westside of the Cascade Range, significant butt decay is indicated by a large fruiting body or swollen butts.
- Elsewhere, the disease may be as common, but it is often present without indicators, especially on dry sites. It is discovered less often until significant wind events and tree failure have occurred.
- While conks may be absent, trees with extensive decay may have pronounced butt swell (Figure 21).
- Decay of the butt extending as much as 30 feet occurs when trees are >150 years old.
- Trees with extensive butt rot often fail under high wind conditions leaving a characteristic barber chair and shattered butt.
- Once trees with fruiting bodies have been identified, or butt swell recognized, those susceptible trees immediately adjacent to them also should be evaluated.
- Tree mortality is unusual unless associated with Armillaria root disease.

- ***Ganoderma butt rot*** *caused by Ganoderma tsugae (the varnish conk) or G. applanatum (the artist's conk)*
    - Ganoderma butt rot affects many conifer and hardwood species but is more common in hardwoods.
    - It occurs in wounded live trees and dead or broken trees.
    - The artist's conk has a dark upper surface and a white underside that stains brown when marked.
    - The varnish conk has a shiny brown upper surface, white underside, and often with a stem or stalk.
    - The decay associated with both conks is a white spongy rot with black flecks.

Heart and sap rot

Heart and sap rots also known as stem decays may compromise bole integrity leading to tree failure

- ***General symptoms and indicators of heart rot***
  - Old injuries to a tree may have resulted in internal decay.
  - Larger wounds, wounds that are in contact with the ground, and older wounds are associated with a greater amount of decay.
  - Resinous tree species are less prone to decay than non-resinous species (see Table 1).
  - Heart rots are most abundant in mature and old growth trees, regardless of their size.
  - Some defect may be hidden or inaccessible to the qualified person.
  - Trees with wounds opening to the outside have a much greater potential for failure than trees having equivalent rinds of sound wood but no open wounds.
  - Heart rot fungi generally need an opening to the heartwood to invade the host. Entry points can be old wounds, branch stubs, or fire scars.
  - When heart rot is extensive within the bole of a tree, it may be indicated by conks, punk knots, or other indicators (Figure 22).
  - Cavity excavation by woodpeckers may indicate heart rot in the tree.
  - The presence of carpenter ant or termite activity can indicate heart rot, especially in wounded trees.
  - Heart rots will sometimes be present when there are few or no external indicators making identification difficult.
  - Trees with split boles or open or bleeding frost cracks are likely to have extensive decay.

There are several important heart rots in Oregon and Washington: rust red stringy rot, red ring rot, brown trunk rot, incense cedar pecky rot, and hardwood trunk rots.

- ***Rust red stringy rot*** *caused by Echinodontium tinctorium (Indian paint fungus)*
  - ♦ This is the most damaging heart rot of mature true firs and hemlocks.
  - ♦ Trees with a single conk have as much as 40 feet of continuous decay.
  - ♦ When decay is advanced, large, hoof-shaped conks with a spiny lower surface are produced (Figure 23).
  - ♦ Conks have a fissured upper surface, and they are rough, dull black, hard and woody.
  - ♦ The interior of the conk and the point of attachment to the tree or branch stub are rusty red to bright orange red.
  - ♦ Conks appear on the bole at the site of old branches and stubs.
  - ♦ Conks with bleeding frost cracks or open cracks indicate extensive decay.
  - ♦ Decay is a rust red stringy rot that may result in nearly hollow stems.
- ***Red ring rot or white speck c****aused by Phellinus pini (ring-scale fungus)*
  - ♦ This is the most common heart rot of Pacific Northwest conifers affecting Douglas-fir, pines, larch, hemlocks, true firs, and spruce.
  - ♦ Conks are hoof-shaped with cinnamon-brown to tan pore surfaces. Pores are irregular rather than round, and the interior of the conk has the same cinnamon brown coloration as the pore surface.
  - ♦ Conks form at branch stubs or over old knots. Several conks in close proximity or numerous conks indicate significant decay (Figure 24).

- Punk knots are common on severely decayed trees (Figure 25). They are evidence that a conk is about to form at an old branch stub, or that a conk was once present at the site but has since fallen off. Punk knots and conks indicate the same amount of decay.
- Unlike other rots, wood decayed by this fungus maintains some strength against failure.
- When trees have many large conks, damage to the heartwood is extensive and tree failure is likely.
- With few or single conks, affected trees may have adequate strength to withstand high wind forces, and tree failure is unlikely.
- Large conks indicate more decay; smaller conks usually indicate less decay, unless the apparent small conks are remnants of larger conks that have fallen off.
- Decay is a white pocket rot that is in rings separated by sound wood until decay is advanced.
- On hemlocks especially, but occasionally on other species, conks may be abundant on the undersides of branches (limb conk and butterfly conk).

- ***Brown trunk rot*** *caused by Fomitopsis officinalis (quinine conk or the chalky fungus).*
  - Several conifer species are affected, and damage is severe stem decay.
  - The fungus enters through trunk wounds or basal fire scars.
  - Conks are rare but unmistakable. They are hard, perennial, hoof shaped to pendulous, and often quite large (Figure 26).
  - Conks have a chalky white to grayish upper surface. Pores are round and the under surface of the conk is chalky white.
  - The interior of most conks is soft and crumbly.
  - Conks develop at branch stubs, over old wounds, or at old top breaks.

- ♦ Punk knots may occur at large, older branch stubs that have usually rotted and fallen off. Punk knots are often seen weeping a yellowish-brown material that stains the bark.
- ♦ A single conk indicates severe stem decay.
- ♦ Decay is a dry brown-cubical rot with thick white mycelial sheets in the decay shrinkage cracks.

- ***Incense-cedar pecky rot*** *caused by Oligiporus amarus*
  - ♦ This heart rot is very common in mature incense-cedar, especially trees greater than 40 inches dbh, and trees with basal wounds or old dead limbs.
  - ♦ Tree failure is not common even with advanced decay.
  - ♦ Decay is not limited to the butt log; it may occur along the entire merchantable length of the bole.
  - ♦ In severely damaged trees, most of the heartwood is decayed.
  - ♦ Conks are common , and incense cedar maintains low failure potential unless there are other indications of extensive decay.
  - ♦ Conks are annual and fruit at knots in summer or autumn.
  - ♦ Conks are hoof shaped to half bell shaped, tan to buff colored on the upper surface, bright sulfur yellow on the underside with small tubes that exude clear drops of a yellow liquid (Figure 27).
  - ♦ Insects, birds, and squirrels destroy conks, leaving a shot-hole cup that is apparent at and below the knot where a conk was attached.
  - ♦ Large open knots or open branch stubs indicate decay.
  - ♦ Woodpecker activity indicates old conk locations and decayed trees.

- ***Hardwood trunk rots***
  - ♦ Several heart rots affect hardwoods, the most common being caused by *Phellinus igniarius, Phellinus*

tremulae, and *Ganoderma applanatum* (the artist's conk). Also causes butt rot. See Ganderma butt rot.

- ♦ Conks of *Ganoderma applanatum* are perennial, leathery to woody, and might have a stalk.
- ♦ The upper surface is smooth with pronounced grooves, dull and often dusty, and gray-brown to dark brown.
- ♦ The conk undersurface is white, creamy, or light brown when fresh and turns brown when bruised.
- ♦ Conks of *Phellinus igniarius* or *tremulae* are hoof-shaped, gray to black on top with conspicuous cracks when old (Figure 28).

- ***General symptoms and indicators of sap rots***
  - ♦ Sap rots are defects unique to the sapwood.
  - ♦ Most sap-rotting fungi cause rapid decay of dead sapwood only.
  - ♦ When these fungi have fully decayed all the available dead sapwood, they have completed their job.
  - ♦ Sap rotting fungi compete poorly with other fungi that decay heartwood, and they are seldom found past the heartwood/sapwood interface.
  - ♦ Sap rots can completely decay tree tops that are often all sapwood.
  - ♦ In living trees, sap rots occur on tissue killed by other agents, usually bark beetles, mechanical damage, or weather damage.
  - ♦ On dead trees, especially those killed by root diseases, fire, and/or bark beetles, sap rot is sure to occur, and the rate of sapwood decay can be rapid.
  - ♦ On some true firs and often hemlocks, sapwood is fully rotted within 2 years.
  - ♦ On other conifers, it may take as many as 3 to 5 years for sap rotting fungi to decay all of the available dead sapwood.

- ♦ A common sap rotting fungus is the pouch fungus (*Cryptoporus volvatus*). When its many little white or gray conks appear completely around the stem, the sapwood is fully rotted (Figure 29).
- ♦ Spores of the pouch fungus are spread by all major species of tree-killing bark beetles.
- ♦ Another common sap rot is caused by the red belt conk (*Fomitopsis pinicola*) (Figure 30). This is the most common decay fungus of dead wood and slash in Oregon and Washington.
- ♦ Hardwoods also have sap rot, and damage may be significant on live trees. As with conifers, sap rotting of hardwoods can occur in dead portions of living trees.
- ♦ On many poplars, maples, and alders, sapwood is decayed very rapidly once it is dead, and there may be few obvious external indicators.

Undermined or severed roots
A compromised root system makes a tree more likely to fall.

- Root disturbance is often seen as undermined or severed roots.
- Undermined roots are often associated with roads or are adjacent to streams or rivers.
- The result of extreme undermining is tree failure from insufficient anchorage.
- Loosened, cracked, broken or severed roots predispose trees to failure in the event of high winds.
- High winds, saturated soils, and soil disturbances often lead to loosening, cracking, or breaking of roots.

Leaning, root-sprung, broken, or uprooted trees supported by other trees

- Root sprung trees are likely to fall because the roots are compromised by being partially pulled out of the ground.
- Root sprung trees are dangerous and are seen as failures in progress.

- Trees with recent leans (<5 years) may have soil and litter not in contact with the base of the tree on the side away from the lean resulting in a conspicuous gap (Figure 31).
- Recent lean may indicate rooting problems that may cause the tree to fall.
- Cracks, mounds, or ridges of recently heaved soil may be adjacent to major lateral roots of leaning trees.
- Leaning trees should be examined for evidence of root and butt rot.
- Tree leans are recent, old, corrected, or uncorrected.
- Recently leaning trees are tilted over their entire length (uncorrected lean). Since there is no evidence of subsequent reinforcement of the root system, trees with recent leans with soil lifting and cracking often fail.
- Corrected leaning trees are those that are leaned over but have subsequently grown a vertical top in the time since the lean occurred. Over time, these trees develop tension and compression wood at stress points to aid in their support. They also often develop a reinforced root system (Figure 32).
- Live or dead broken or uprooted trees supported by other trees have a failure potential that is determined by their amount of support.

Cracks and structural defects

- Cracks and structural defects in the main stem may cause a tree or its parts to fail.
- Dangerous cracks show movement of the wood on either side of the crack.
- Open cracks may be associated with substantial decay.
- Cracks and defects with significant decay are more likely to fail.
- Cracks form by tension and compression failure when trees with extensive heart rot bend back and forth under the stress of high winds. The result is a vertical crack in the bole between the ground and where the heart rot is greatest.

- Cracks may be formed by lightning strikes (Figure 33). Damage from lightning can be highly variable, ranging from shallow spiraling furrows that just penetrate the bark, to cracks that may be several inches wide and penetrate deep into the wood.
- Under the influence of frequent high winds, trees often develop shake or separations in the lowest section of the butt (Figure 34). The twisting action of the wind first causes separations to develop along the growth rings.
- Frost cracks are formed by the action of extreme cold (Figures 35). Frost cracks, appear on bark as raised nearly vertical callus lines which extend to the ground where frosty air is coldest. These cracks begin at the tree base, usually from an old wound, and seldom go higher than 5 feet up the bole.
- Healed frost cracks that are not weeping, seldom result in tree failure.

Dead tops and large dead branches, detached tops, limbs, and loose bark

- Dead tops can result from insect attack, dwarf mistletoe, or rust fungi.
- Dead tops and large branches (≥5 in. large-end diameter) with evidence of decay may break apart and fail (Figure 36).
- Dead tops and branches of cedar or larch rarely fail.
- Pine tops and branches killed by rust fungi such as white pine blister rust or comandra rust have extensive resin soaking, are very decay resistant, and do not often fail (Figure 37).
- Dead tops and branches killed by insects differ from rust-killed tops and branches because they are killed all at once rather than progressively, contain sap rot fungi, and are more likely to decay and fail than rust-killed tops or branches.
- Dead tops and branches of Douglas-fir, spruce, larch, or pine are resinous and more resistant to failure.

- Dead tops and branches of true firs, hemlock, or hardwoods are non-resinous, are highly susceptible to attack by decay fungi, and are more likely to fail than other tree species.
- Dead tops without bark are more likely to fail than newly killed tops.
- Detached tops, limbs, or loose bark often fall and are extremely dangerous.
- Live, large branches on mature cottonwoods can fail especially if previous breakage has occurred.

Forked or multiple tops

- Live trees with forked tops or multiple (candelabra) tops can fail at the base of the top.
- Forked tops with crotches that are tightly V-shaped can split and break from the green weight of foliage, heavy snow loads, wind, or internal decay.
- This also occurs in hardwoods with large, spreading crowns.
- Trees with deformed tops should be examined for cracks, splits, embedded bark, and callus ridges that indicate weakening and predisposition to failure or infection by decay fungi.
- Mushrooms or conks associated with deformed tops indicate internal decay.
- Forked tops that are U-shaped rarely fail.

Dwarf-mistletoe brooms

- Dwarf mistletoes are parasitic plants that cause branches of some tree species to become misshapen. These deformed branches are called witches-brooms (Figure 38).
- Large dead dwarf mistletoe brooms on Douglas-fir and sometimes on ponderosa pine can become weighted with snow and ice and fail.
- Dead brooms >10 ft. in diameter often fail.

- Smaller dead brooms and live brooms are less likely to fail.

Fungal cankers, bole wounds, and mistletoe bole swellings

- Fungal cankers frequently occur on the boles of pine species, especially ponderosa and lodgepole pines (Figure 39). Western gall rust, comandra rust, and white pine blister rust cause cankers.
- Wounds on tree boles provide openings for decay fungi and often indicate internal decay depending on tree species.
- Canker fungi cause top kill, branch death, and stem malformation.
- Stem malformations increase stem breakage and can be decayed by other fungi.
- Dwarf mistletoe bole swellings are caused by mistletoe infection of the bole (Figure 40). Swellings are especially common on grand and white fir, western and mountain hemlock, and occasionally western larch.
- Dwarf mistletoe bole swellings can become decayed and result in tree failure.
- True fir, hemlock, spruce, or hardwoods with cankers, wounds or swellings are more likely to fail than the resinous species.
- Douglas-fir, cedar, pine, and larch are less likely to fail because of resin-impregnated or decay-resistant wood.
- Resinous wood around cankers, wounds, and bole swellings usually remains sound.
- Failure level does not significantly increase until the face of the canker is deeply sunken, and the cross section of the bole with sound wood is small.

Fire damage

- Tree boles or limbs may be so badly burned that portions of them are missing which may cause the bole or limb to break and fall.

- Root systems may be damaged by fire, and the entire tree may fall.
- Before burning, the tree may have had conks that indicate severe decay. They may have burned off, eliminating the indicators of root disease or heart rot. Therefore, the tree may be more unstable than the visible indicators suggest.
- Likelihood of failure is determined by tree species (resinous or non-resinous), the amount of sound wood remaining, and time since tree death.
- Large pines, larch, or Douglas-fir with old basal fire scars may have compensated for any defect or decay by increasing their butt diameter; such trees rarely fail.
- Fire damaged trees may still have green crowns but dead cambiums at their base, essentially a dead tree.
- Long lasting and smoldering fires at the bases of large pines usually kill the fine roots and eventually the tree.

Height-to-diameter ratio

- Live trees with a high height-to-diameter ratio may fail depending on the ratio.
- These trees can break or bend permanently usually from snow or ice loading in the winter, especially if dwarf mistletoe brooms are present.
- To calculate height-to-diameter ratio, estimate the total tree height in feet and divide by the diameter at breast height (dbh) measured to the nearest foot. For example, a tree 100 ft. tall and 1 ft. dbh would have a height-to-diameter ratio of 100.

Insect-caused damage

- Forest insects can weaken roots, stems, tops, or branches and result in fungal decay and physical degradation.
- Insects interact with fungal pathogens to cause damage or directly kill trees or their parts.
- Bark beetles are the most important insects that result in tree mortality. Chief beetles are the Douglas-fir beetle, fir

engraver, spruce beetle, mountain pine beetle, western pine beetle, and pine engraver.

- Bark beetles frequently attack trees that are stressed from root disease, bole damage, defoliation, or drought.
- Symptoms of bark beetle attack are boring dust, pitch streams, galleries under the bark, fading or red crowns, dead tops, or group mortality (Figure 41).
- Wood borers are similar to bark beetles but prefer even weaker trees than bark beetles.
- Bark beetles and wood borers introduce saprot fungi after trees are killed.
- Carpenter ants and termites can severely weaken trees that are already decayed.
- The balsam woolly adelgid causes widespread mortality of subalpine fir and, in some cases, pacific silver fir and westside grand fir. Tree failure eventually may occur in infested live trees with little green crown remaining (Figure 42).
- Defoliating insects such as the western spruce budworm and the Douglas-fir tussock moth can kill tops or entire trees.

Multiple defects

The potential for tree failure increases dramatically with the combined effects of multiple defects such as heart rot and cankers, or stem injury, root rot and lean, split crotches and heart rot, and wind shake and butt rot.

Figure 5 Crown decline from root disease

Figure 6 Basal resinosis

Figure 7 Armillaria root disease mushrooms

Figure 8
Wind throw &
wind shatter

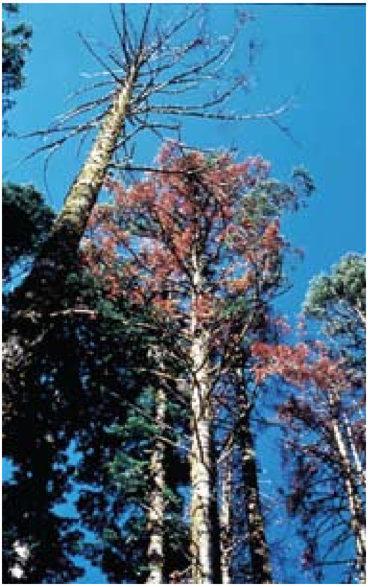

Figure 9 Dead and dying trees caused by root disease

Figure 10 Bark beetles often attack trees stressed by root disease

Figure 11 Decay associated with laminated root rot

Figure 12 Wind throw of live infected trees caused by laminated root rot

Figure 13 Armillaria mycelial fans

Figure 14 Annosus root disease conks

Figure 15 Annosus root disease pustules

Figure 16 Annosus root disease wind throw

Figure 17 Tomentosus caused wind throw

Figure 18 Tomentosus root rot mushrooms

Figure 19 Brown cubical butt rot old conk

Figure 20 Brown cubical butt rot fresh conk

Figure 21 Butt swell caused by brown cubical butt rot

Figure 22 Conks are good heart rot indicators

Figure 23 Rust red stringy rot conks, Indian Paint fungus

Figure 24 Red ring rot conks, Phellinus pini

Figure 25 Red ring rot punk knot

Figure 26 Brown trunk rot quinine conk

Figure 27 Incense cedar pecky rot conk

Figure 28 Phellinus tremulae conk on decayed aspen

Figure 29 Sap rot conks, Cryptoporus volvatus

Figure 30 Red belt conk, Fomitopsis pinicola

Figure 31 New lean, soil cracking

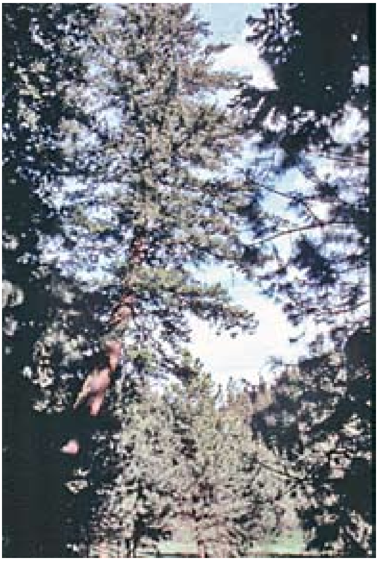

Figure 32 Corrected old lean

Figure 33 Crack from lightning strike

Figure 34 Crack from wind damage

Figure 35 Frost crack

Figure 36 Dead top

*Figure 37
Comandra rust
killed top in pine*

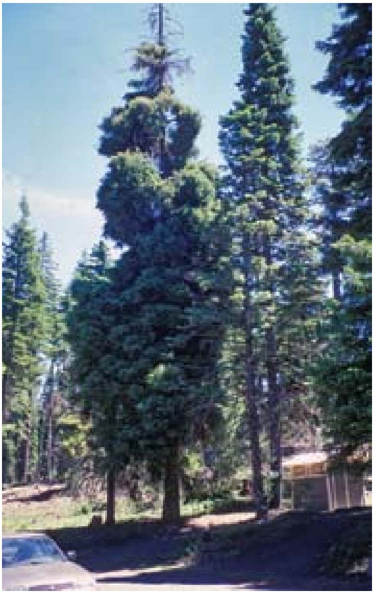

Figure 38 Dwarf mistletoe brooms

Figure 39 Atropellis canker on lodgepole

Figure 40 Dwarf mistletoe bole swelling

Figure 41 Fir engraver galleries

Figure 42 Balsam woolly adelgid damage

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